# Overtopping Modifications to Tygart Dam

Mark P. Zaitsoff, P.E.[1]

## Background

Tygart Dam is located in the northern part of West Virginia on the Tygart River in Taylor County. The dam is located approximately 2 miles upstream of the city of Grafton and 23 miles upstream of the city of Fairmont where the Tygart and West Fork Rivers join to form the Monongahela River (Figure 1).

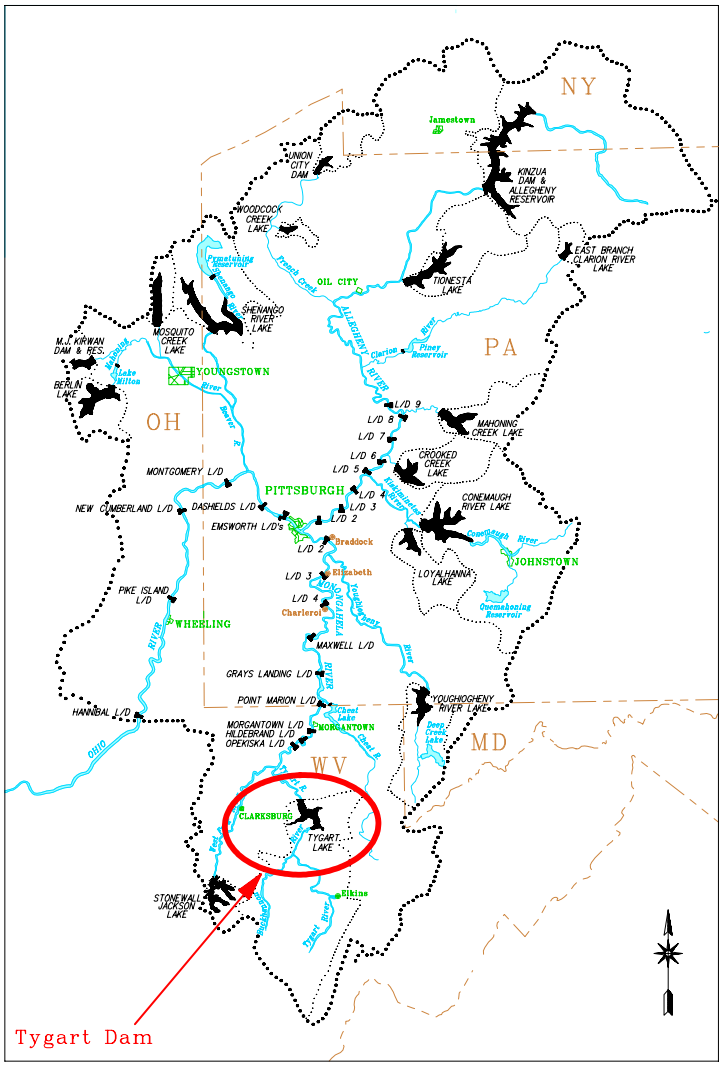


**Figure 1**. Location Map

[1] Hydraulic Engineer, Hydraulics and Hydrology Section, Pittsburgh District, CELRP-EC-WH, 1000 Liberty Avenue, Pittsburgh, PA 15222-4186, 412-395-7351, Mark.P.Zaitsoff@USACE.army.mil

Tygart Dam is a concrete gravity type structure with an uncontrolled spillway located approximately in the center of the dam (Figure 2). The total width of this spillway is 489 feet. Abutment sections on each side of the spillway extend 23 feet above the spillway crest to a roadway with four foot high parapet walls. The overall length of the dam is 1921 feet. The crest of the spillway is at elevation 1167 FT NGVD and is 234 feet above the streambed.

**Figure 2**. Tygart Dam (before modifications)

The Public Works Administration initially authorized the Tygart Dam project in 1934. The Rivers and Harbors Act of 1935 directed the Corps of Engineers to assume responsibility for the project; the Pittsburgh District has operated and maintained it since construction was completed in 1938.

**The Problem**

Tygart Dam was hydrologically and hydraulically deficient according to current Corps of Engineers standards. The dam, properly designed and built in the mid 1930s, no longer met today's updated and revised dam safety standards.

The policy on hydrologic/hydraulic criteria requires that the dam meet a base safety condition (BSC). The BSC is met when a dam failure related to hydrologic capacity will result in no significant increase in downstream hazard over that which would have existed if the dam had not failed. The BSC for Tygart Dam is the probable maximum flood (PMF). The dam has inadequate discharge and storage capacity to safely pass the PMF without overtopping.

The spillway will safely pass a discharge of 200,000 cubic feet per second (CFS) with a freeboard of one foot below the roadway elevation and five feet below the top of the

parapet walls. The current estimate of the PMF is 375,350 CFS, 88% greater than the spillway capacity. The PMF will result in a maximum water surface of about 2.5 feet above the top of the parapet walls; the duration of overtopping will be about 11 hours.

Overtopping flows will impinge on the downstream abutments and toe and scour foundation material from an area critical to the stability of the dam. An overtopping of this magnitude is likely to cause sudden and complete failure of the structure. The failure of Tygart Dam by overtopping would occur as sliding or overturning of one or more monoliths due to undermining and loss of toe support. The failure of one monolith would probably cause adjoining monoliths to fail due to loss of lateral support and undermining by concentrated flow through the breach. Based on documented failures of other dams, a failure of Tygart Dam caused by overtopping probably would be complete, sudden and with little visible sign of distress.

**The Study**

The Pittsburgh District undertook a Dam Safety Assurance Study to determine the threat to the structure and to develop a fix. The District evaluated several alternatives that would allow the dam to safely pass the PMF.

The structure was constructed with two penstocks for potential hydropower development. However, they are currently plugged with concrete. An inlet structure, penstock extensions and outlet structures would be necessary before the penstocks could be used. The hydraulic analysis showed that they could not pass enough additional flow to allow the dam to safely pass the PMF; the penstocks were eliminated from further consideration.

An auxiliary spillway through the right abutment of sufficient size to carry the excess flow from the spillway is possible. The spillway cut would be 225 feet wide and a maximum of about 80 feet deep. It would cut through the project office parking lot, require relocating several residences, relocating roads, and constructing a new bridge to span the spillway. This alternative was eliminated due to cost.

Modifications to the existing spillway were considered. The spillway crest would be lowered 7 feet and a pier and two inflatable rubber dams with a central pier would be added. The rubber dams would provide storage up to the existing crest elevation, and then deflate to allow flood discharges. The stilling basin would have to be extended downstream and the spillway training walls raised to accommodate the increased discharge. This alternative was eliminated due to cost.

Raising the top of dam to prevent overtopping was also considered. The upstream parapet walls would have to be raised 6 feet to allow the existing spillway to pass the PMF without the dam overtopping. The stilling basin would have to be extended downstream and the spillway training walls raised to accommodate the increased discharge. This alternative was eliminated due to cost and because of the extensive changes to the historically significant architecture of the structure.

Allowing the dam to overtop was evaluated as an alternative. This alternative would require structural modifications to the dam to ensure its stability and possible extension of the stilling basin.

**The Fix**

The study evaluated these alternatives and recommended that, with structural modifications, the dam be allowed to overtop. The overtopping alternative was then physically modeled to validate and refine the modifications. The modeling was conducted at the Waterways Experiment Station at a cost of $515,000. The modeling confirmed that the existing stilling basin would perform adequately and would not need to be extended; this saved about $18,000,000 from the cost of the project.

Before the structure overtops the water will backflow through the road drains onto the roadway. When the structure overtops the water will first flow over the upstream parapet wall, completely fill the roadway area and then flow over the downstream wall. Structural analysis showed that the parapet walls were strong enough to withstand the overtopping flow. The deteriorating concrete on the walls was repaired and the roadway resurfaced (Figure 3).


**Figure 3.** Looking toward west abutment at parapet walls and roadway repairs

The water that fills the roadway area would flow to each abutment and down them to the toe of the structure. Walls have been added at the downstream side of each abutment to prevent the overtopping flow from flanking the dam (Figure 4).

**Figure 4.** Wall at east abutment and reconstructed east access road

The doors and windows at the top of the structure will be submerged during the overtopping of the structure. The roadway area will be flooded and the top of dam inaccessible for an estimated 21 hours. Failure of a door or window would allow the water to flood the interior of the structure possibly leaving the dam inoperable for an extended period of time. All doors and windows, below the overtopping elevation, have been replaced with watertight units or provided with watertight covers (Figure 5).

**Figure 5**. Watertight door and window in the east stairway building

The overtopping flow will plunge over the downstream parapet wall onto the downstream face of the dam. Concrete channels and paving have been constructed to guide the high velocity overtopping flows down each abutment slope into the stilling basin and river channel and to protect the downstream toe of the structure (Figures 6 and 7). The channels vary from 30 feet wide and 5.5 feet deep at the top of the slope to 80 feet wide and 8 feet deep at the bottom. The flat areas at the toe of the structure have been paved to the extent of the stilling basin walls; stone protection was considered but would have limited access to the toe of the structure.

**Figure 6.** Concrete paving and channel on east abutment

**Figure 7.** Concrete paving and channel on west abutment

The two adits at the toe of the structure, which provide access to the operating gallery, will be impacted by the overtopping flow and submerged by the PMF tailwater for an estimated 20 hours. Failure of an adit would lead to the flooding of the operating and lower galleries with resultant damage to the sluice and ring jet controls. The adits were rebuilt to withstand the overtopping flow's impact and provided with watertight doors while maintaining the historically significant architecture of the structure. Access galleries to the low flow ring jet valves were provided with watertight hatches (Figure 8).

**Figure 8.** Reconstructed east adit and access hatch to ring jet valve

An additional feature of the project was the construction of an access road to the west abutment. There had been no vehicular access to the west abutment since the dam was completed in 1938; the only access was by walking through the dam galleries or by climbing up the west abutment slope from the toe of the dam. A new road was built to provide access during construction and for future maintenance access (Figure 9).


**Figure 9.** West access road looking toward west abutment

## Conclusions

Tygart Dam has provided 65 years of flow augmentation and flood control for the Monongahela River. The completion of the modifications to the structure ensures that it meets the current dam safety standards.

## References

Dam Safety Assurance Evaluation Report, Tygart Dam West Virginia, U.S. Army Corps of Engineers, Pittsburgh District, November 1995